Further Analysis of I/M Failure Rates by Vehicle Model

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Last year we presented an analysis of IM240 failure rates by vehicle model from the Arizona IM240 testing program in 1995. This year we look at three test years of Arizona data to examine the internal consistency of the data. We also present a comparison of failure rates and average emissions by vehicle model from several IM240 programs.

Consistency of AZ data

We compared IM240 failure rates by model for three test years, 1995 through 1997. We only include the first six months of each year in the analysis, in order to ensure that at least 6 months elapsed between all of the tests conducted in each test year. Arizona operates a biennial inspection program, with half of all vehicles from each model year tested every year. Vehicles are not tested when they are resold. Therefore, the same vehicles that were tested in 1995 are tested again in 1997, unless they moved out of the I/M area or were scrapped.

Figure 1 plots HC failure rates for 194 model year 1990 to 1993 car models tested in 1996 against those tested in 1997. Each point on the figure represents a model year/model (e.g. 1993 Nissan Sentra), for which at least 80 individual cars were tested. The failure rates are quite similar in the two test years, with the same models having the highest failure rates in each year. The figure is typical of the other year-to-year comparisons for each pollutant. The table shows that the r-squared values for each year-to-year comparison for each pollutant range from 0.66 to 0.90. The comparisons with the lowest (Figure 2) and highest (Figure 3) correlation are also presented.

Table 1. Consistency of AZ IM240 Model Failure Rates over Time: R^2 of Year-to-Year Comparisons

Test Year Comparison	HC	CO	NOx
194 MY90-93 Car Models			
1995 vs. 1996	0.84	0.74	0.90
1996 vs. 1997	0.78	0.70	0.88
1995 vs. 1997	0.76	0.66	0.80
154 MY87-89 Car Models			
1995 vs. 1996	0.87	0.89	0.85
1996 vs. 1997	0.86	0.87	0.82
1995 vs. 1997	0.85	0.87	0.77

Close analysis of the plots indicates that CO failure rates by MY/model tend to increase over time. That is, the points in Figure 4 tend to be above the (solid) 45-degree line, indicating that CO failure rates by model increased from 1995 to 1996. This is to be expected, since the individual vehicles tested in 1996 would on average be at least 6 months older, and likely have accumulated more mileage, than the vehicles tested in

1995. We see a similar increase in failure rate from 1995 to 1997 (Figure 2); these are the same cars that went through the I/M program in 1995. It appears that the Arizona I/M program roughly offsets one year of the "natural" emissions increase due to vehicle aging and mileage accumulation. We are further analyzing the effect of the I/M program on failure rates and emissions by tracking individual vehicles over several test years.

Figure 1. HC Failure Rates, 194 MY90-93 Car Models, AZ IM240
(at least 80 individual cars tested for each model)

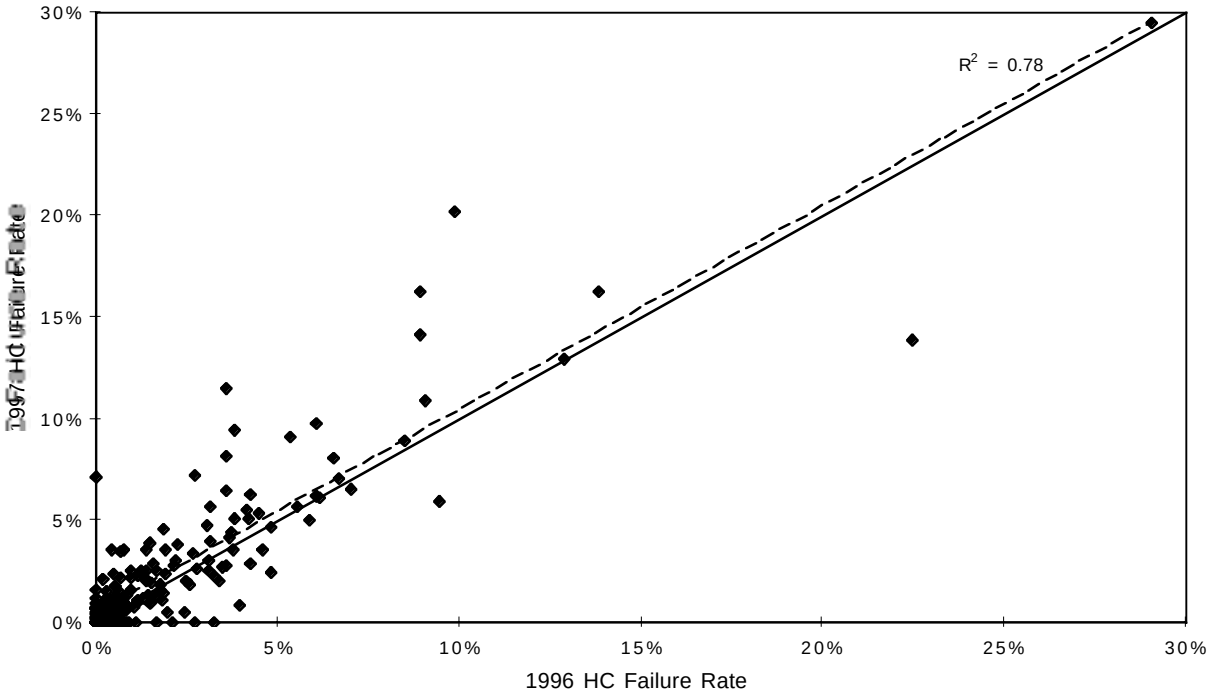


Figure 2. CO Failure Rates, 194 MY90-93 Car Models, AZ IM240
(at least 80 individual cars tested for each model)

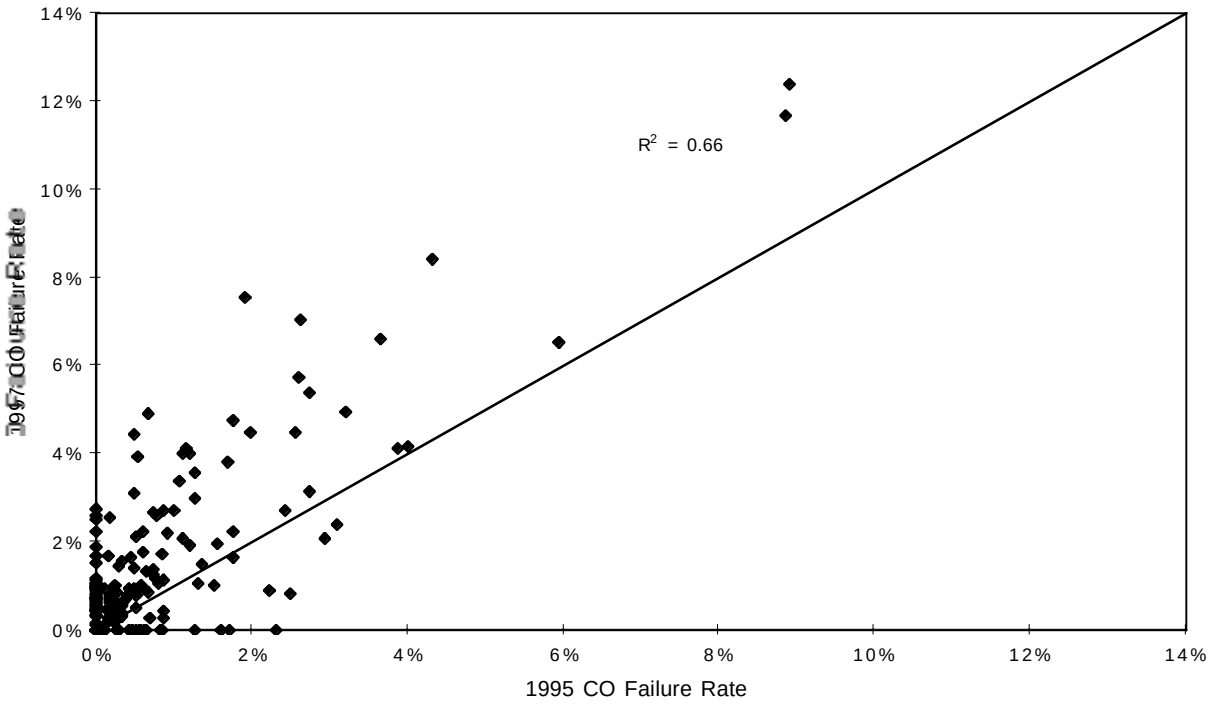


Figure 3. NOx Failure Rates, 194 MY90-93 Car Models, AZ IM240

(at leat 80 individual cars tested for each model)

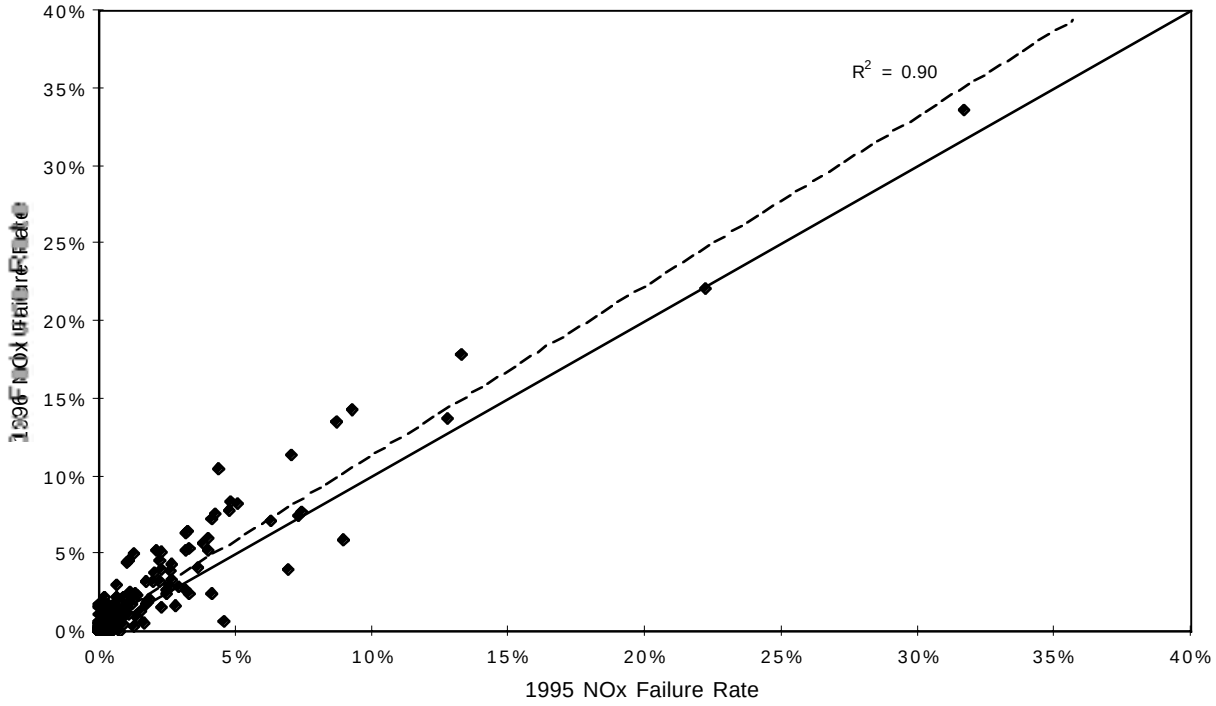
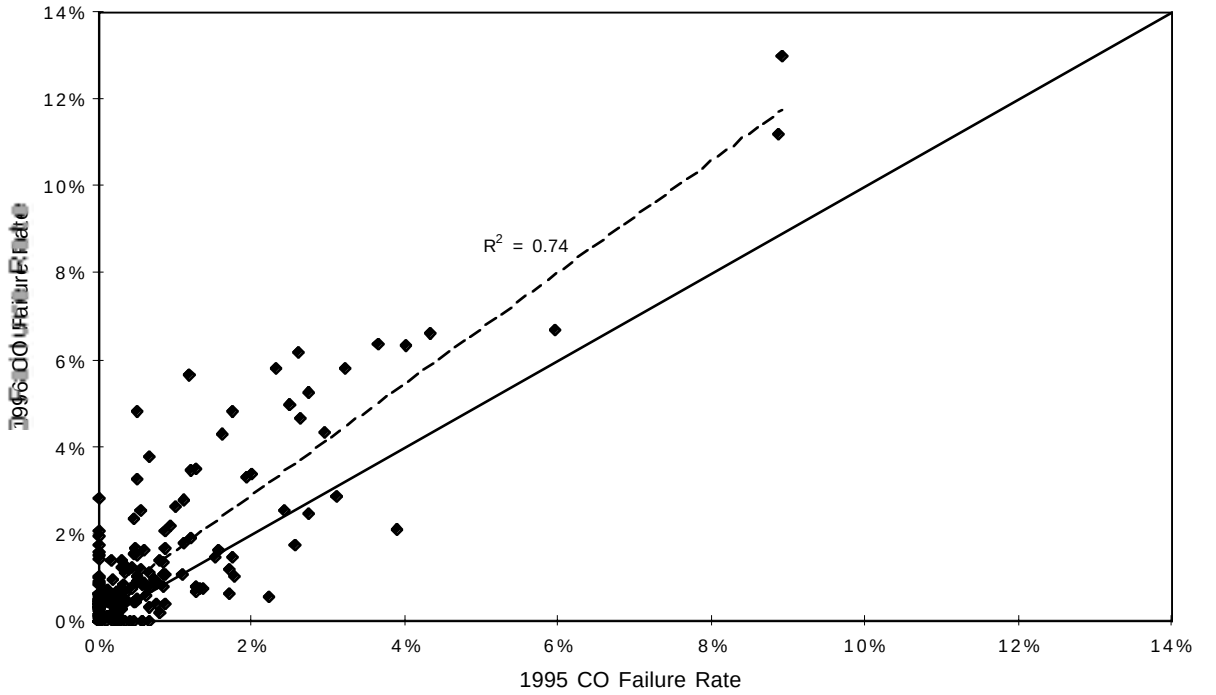


Figure 4. CO Failure Rates, 194 MY90-93 Car Models, AZ IM240

(at least 80 individual cars tested for each model)



Accuracy of I/M emissions results

We next compared failure rates by model to average emissions by model. A limitation of I/M data is that testing procedures are not consistent between vehicles. States like Arizona allow the cleanest vehicles to pass after 30 seconds of testing (fast passes), while the dirtiest vehicles are failed after 94 seconds (fast fails). This means that all vehicles are not tested over the same portion of the IM240 test procedure. To compare emissions from vehicles tested over different portions of the IM240, one needs to correct fast pass/fast fail emissions to full test equivalent values. We use a simple methodology to convert short test results to full test equivalent emissions. This methodology uses correction factors based on the average ratio of emissions at each second to full test emissions, for each pollutant and second of the IM240. For our purposes here, we do not require that this correction results in absolute accuracy for individual vehicles; rather we look for consistent ranking of models.

Arizona runs full IM240 tests on a random sample of 2 percent of the vehicles in the fleet. (Unfortunately we could not distinguish between vehicles given the full test because they were part of this random sample or because they had emissions close enough to the cutpoints that they could neither fast pass or fast fail. It appears that only one-half of the vehicles given an initial full IM240 were part of the random sample). Figures 5a through 7a compare the average emissions of full tests with those of short tests, by vehicle model, for each pollutant. Each plot shows relatively good agreement between the average emissions of vehicles given the full test, and those either fast passed or fast failed, with r-squared values of 0.68 (for NOx) to 0.87 (for CO). The vehicles given the full test appear to have consistently higher emissions than those fast passed or fast failed. Much of this difference is likely due to the crudeness of our adjustment factors; our analysis indicates that our factors tend to underestimate emissions from all cars, and in particular the cleanest cars which make up the majority of the fleet. It is also possible that the random sample of vehicles receiving the full test are not representative of the fleet. If one is concerned only with relative emissions values, it appears that the IM240 short test emissions values can be used to compare groups of vehicles. If one is interested in absolute emissions, however, a better method to project full test emissions is needed.

Figures 5b through 7b show the value of using the average emissions values for vehicles receiving the short test. These figures are identical to Figures 5a through 7a, with the standard error of each estimate included. The vertical “whiskers” are the error associated with the full test cars, while the horizontal whiskers are the error of the short test cars. As the figures show, an order of magnitude increase in the sample size greatly reduces the uncertainty of the estimate of average emissions by model.

Figure 5a. Average HC by Model, Fast Pass/Fast Fail vs. Full Tests

MY90-93 models with at least 10 full IM240 tests, 1995 AZ IM240

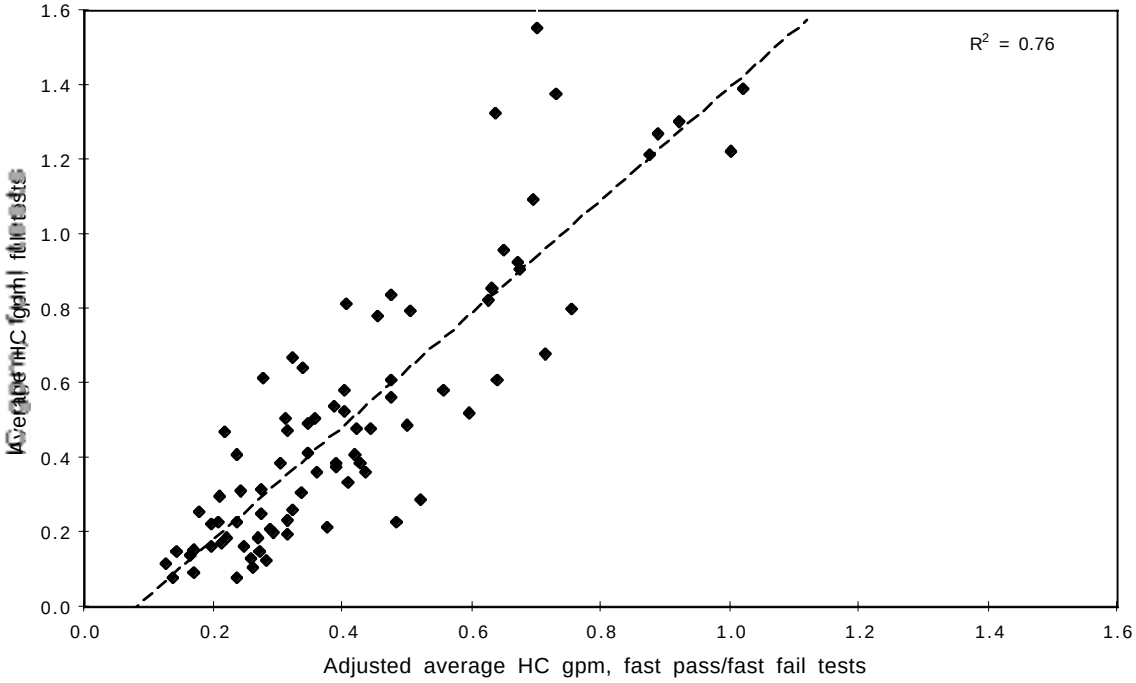


Figure 5b. Average HC by Model, Fast Pass/Fast Fail vs. Full Tests

MY90-93 models with at least 10 full IM240 tests, 1995 AZ IM240

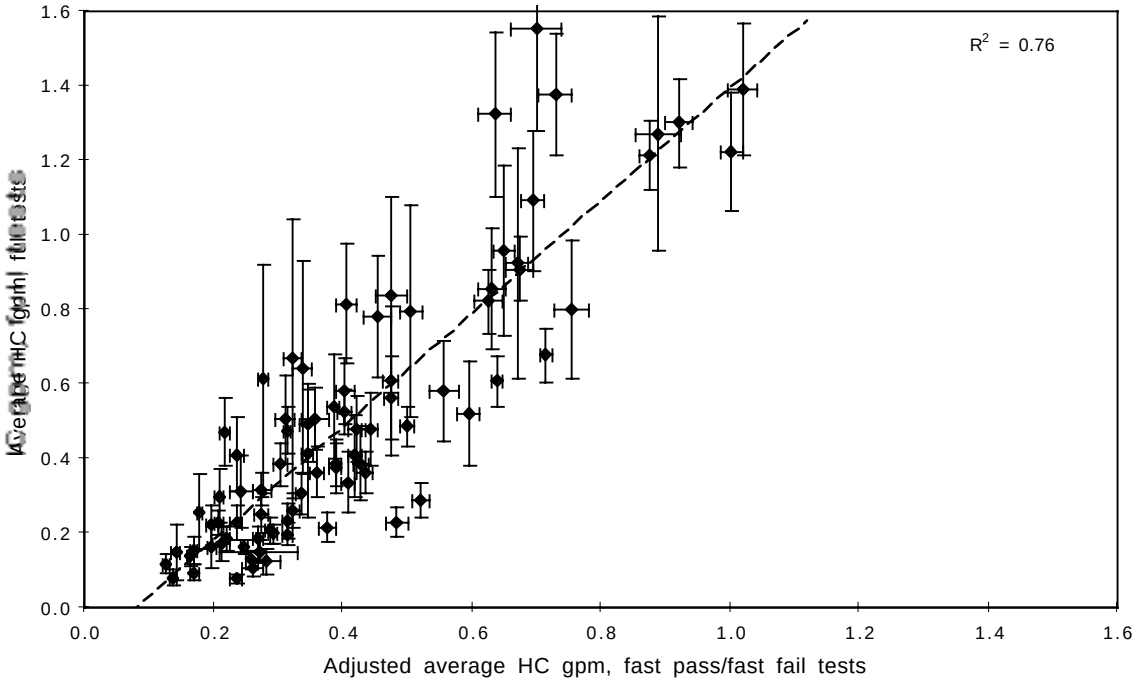


Figure 6a. Average CO by Model, Fast Pass/Fast Fail vs. Full Tests

MY90-93 models with at least 10 full IM240 tests, 1995 AZ IM240

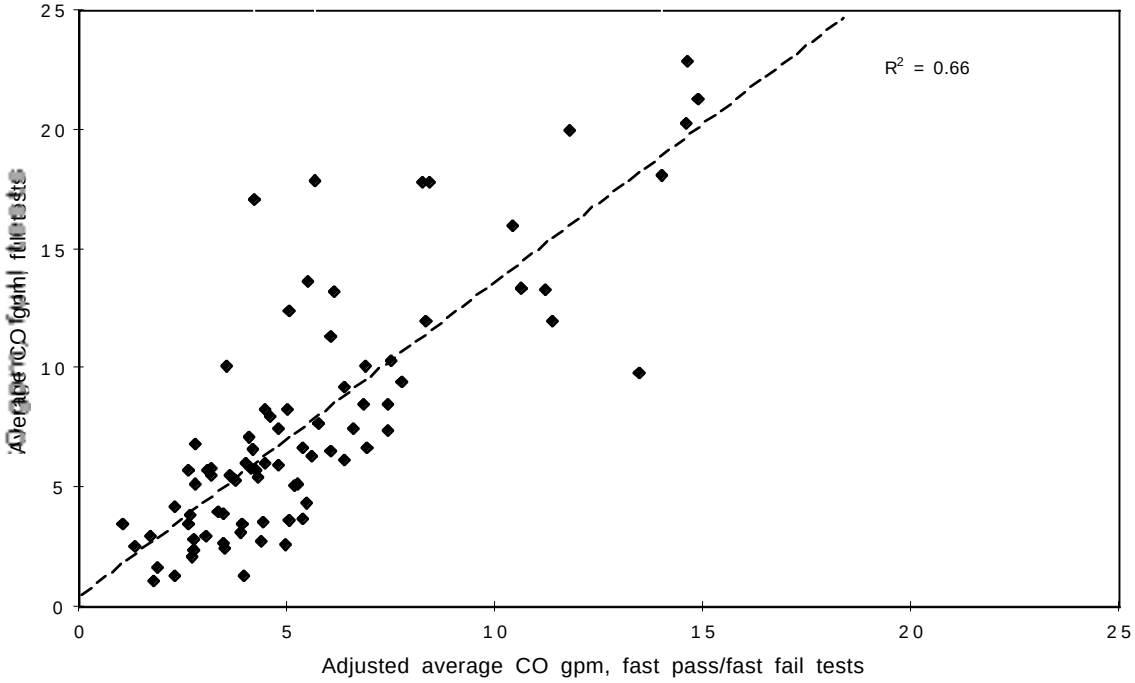


Figure 6b. Average CO by Model, Fast Pass/Fast Fail vs. Full Tests

MY90-93 models with at least 10 full IM240 tests, 1995 AZ IM240

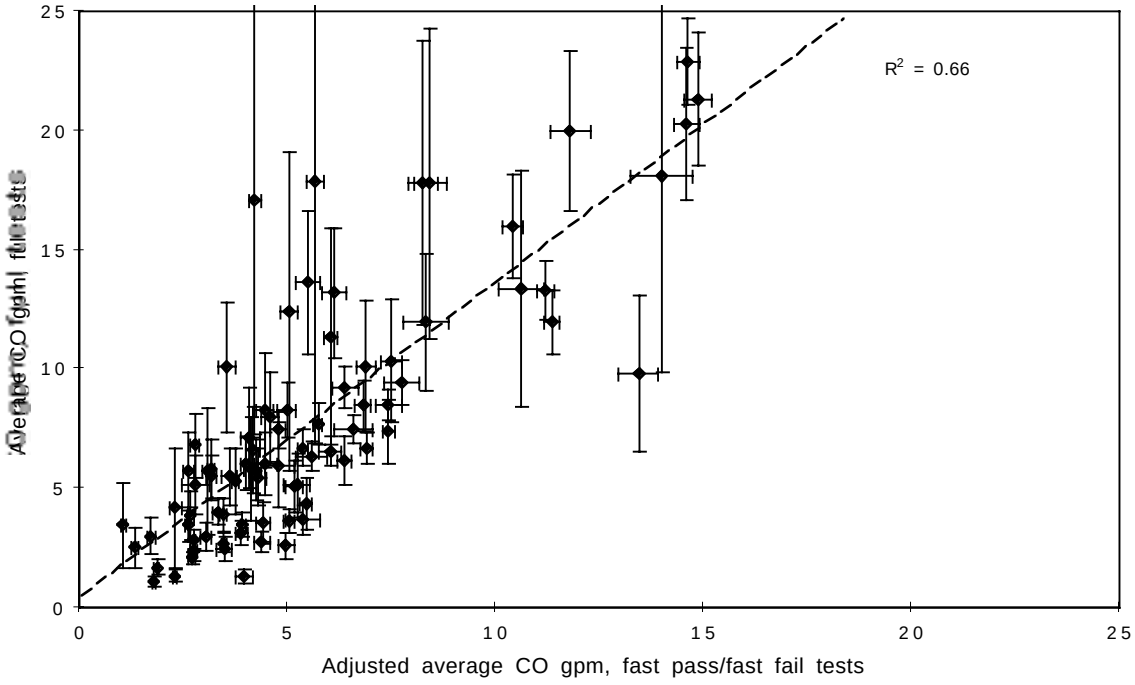


Figure 7a. Average NOx by Model, Fast Pass/Fast Fail vs. Full Tests

MY90-93 models with at least 10 full IM240 tests, 1995 AZ IM240

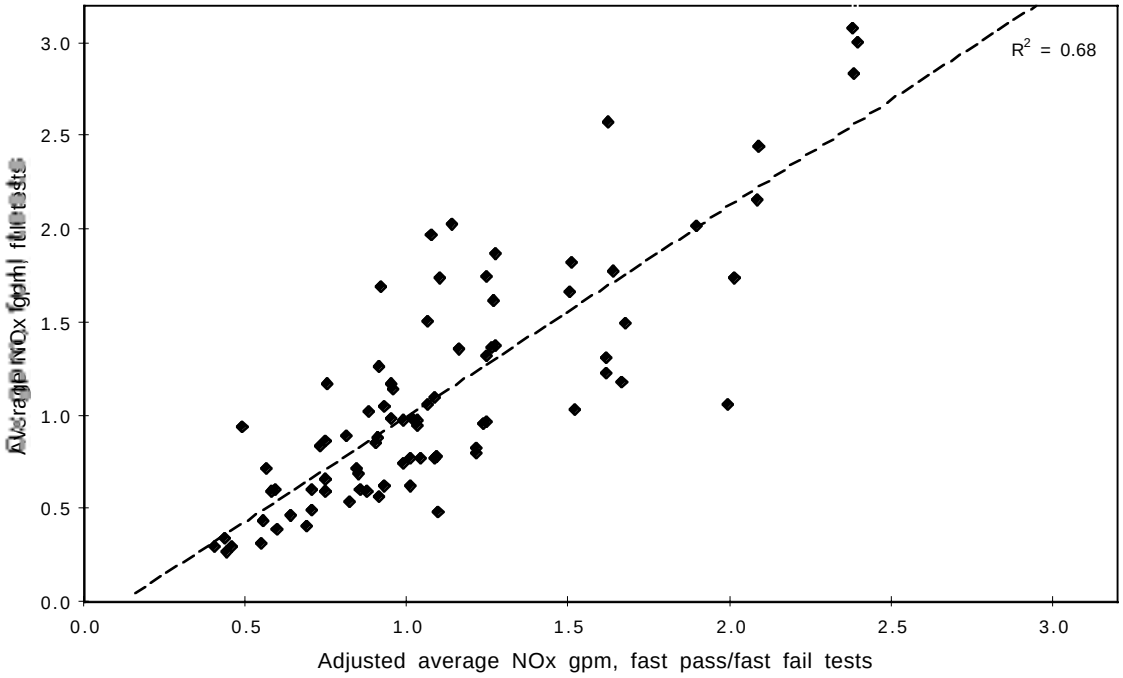
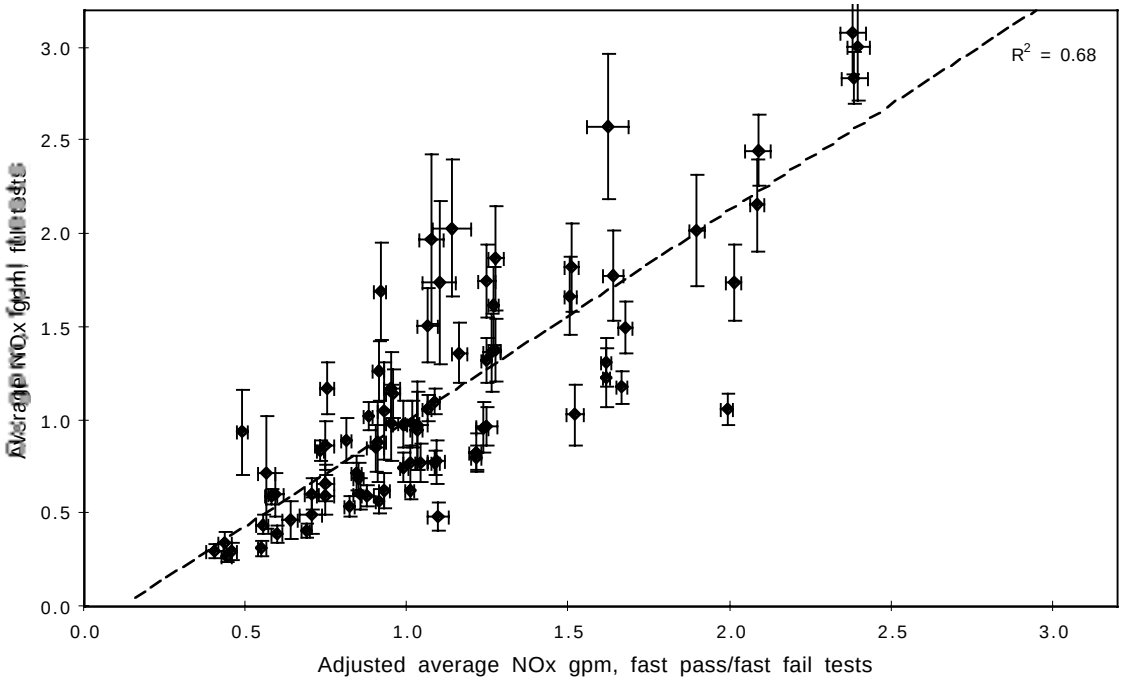


Figure 7b. Average NOx by Model, Fast Pass/Fast Fail vs. Full Tests

MY90-93 models with at least 10 full IM240 tests, 1995 AZ IM240



Interstate comparison of IM240 failure rates

We compared failure rates by model from three states that are using the IM240 test procedure: Arizona, Colorado, and Wisconsin. Table 2 summarizes the key features of each program. Important differences are the cutpoints (Arizona's and Wisconsin's are similar, while Colorado's tend to be less stringent), and the model years tested in each year (while Arizona tests all model years each year, Colorado tested only odd model years in 1997 and Wisconsin tested only even model years). Figures 8 through 10 compare the 1997 combined CO and HC failure rates for 36 selected models; we show CO and HC failure rates only because Wisconsin did not fail vehicles based on NOx emissions. The models studied were chosen because they are popular models and had few engine and transmission options; we wanted to avoid including cars with different sized engines in the same model.

Figure 8 shows good agreement between the Arizona and Wisconsin programs; the relative rankings of the models by failure rate are quite similar. The good agreement may in part be due to the sample of models studied; we only looked at a few models from each of a wide range of model years. Since one expects failure rates to increase as vehicles age, it is no surprise that the oldest models have the highest failure rate in each state. Still, the agreement is quite good if one accounts for model age. The Colorado data do not agree as well with those of the other two states (Figures 9 and 10). This may be due to the different cutpoints used in Colorado. We plan to do a more thorough interstate analysis of failure rate by model, to more fully examine the consistency of emissions by model across different I/M programs.

Table 2. IM240 Program Elements in Three States

Program Element	Arizona	Colorado	Wisconsin (1)
Test Cycle	biennial; all MYs tested in 1997	biennial; odd MYs tested in 1997	biennial; even MYs tested in 1997
Test on Resale?	no	yes	yes
Composite Cutpoints (cars)			
HC	91-95: 1.2 81-90: 2.0	86-95: 4.0 82-85: 5.0	91-95: 1.25 81-90: 2.0
CO	91-95: 20 83-90: 30 81-82: 60	91-95: 20 85-90: 25 83-84: 50 82: 65	91-95: 20 83-90: 30 81-82: 60
NOx	91-95: 2.5 81-90: 3.0	95: 4.0 86-94: 6.0 82-85: 8.0	*91-95: 2.5* *81-90: 3.0*
Fast Pass?	yes	yes	yes
Fast Fail?	yes	no	no
Phase 2 Pass?	yes	no	yes
Second Chance to Pass?	no	yes if emissions <2x cutpoint	yes if emissions <2x cutpoint
Full Tests	random 2%	all vehicles tested 1/97 to 3/97	random 2%

(1) Cutpoints shown were effective 12/96 to 11/97. Although Wisconsin tests for NOx, vehicles are not failed for exceeding NOx cutpoints. Vehicles tested during weekends in 1996 were given full test; this practice was replaced by 2% random sampling in 1997.

Figure 8. AZ v. WI 1997 IM240 Combined CO and HC Failure Rates
Selected Models

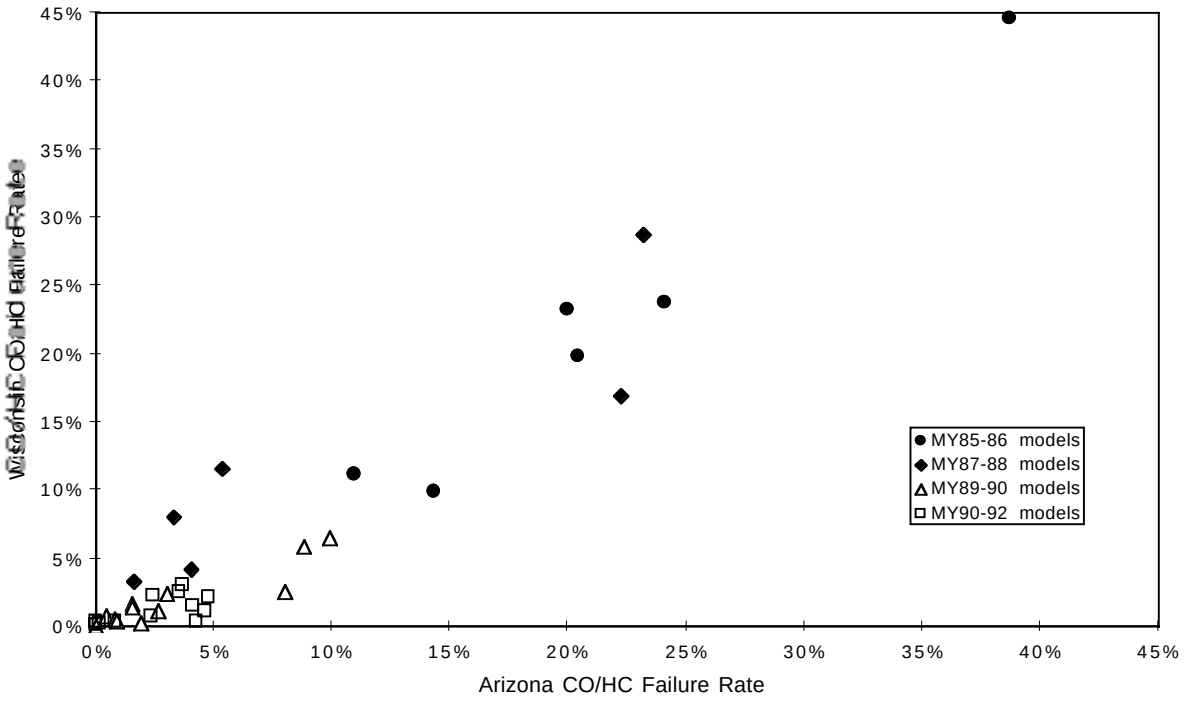


Figure 9. AZ v. CO 1997 IM240 Combined CO and HC Failure Rates,
Selected Models

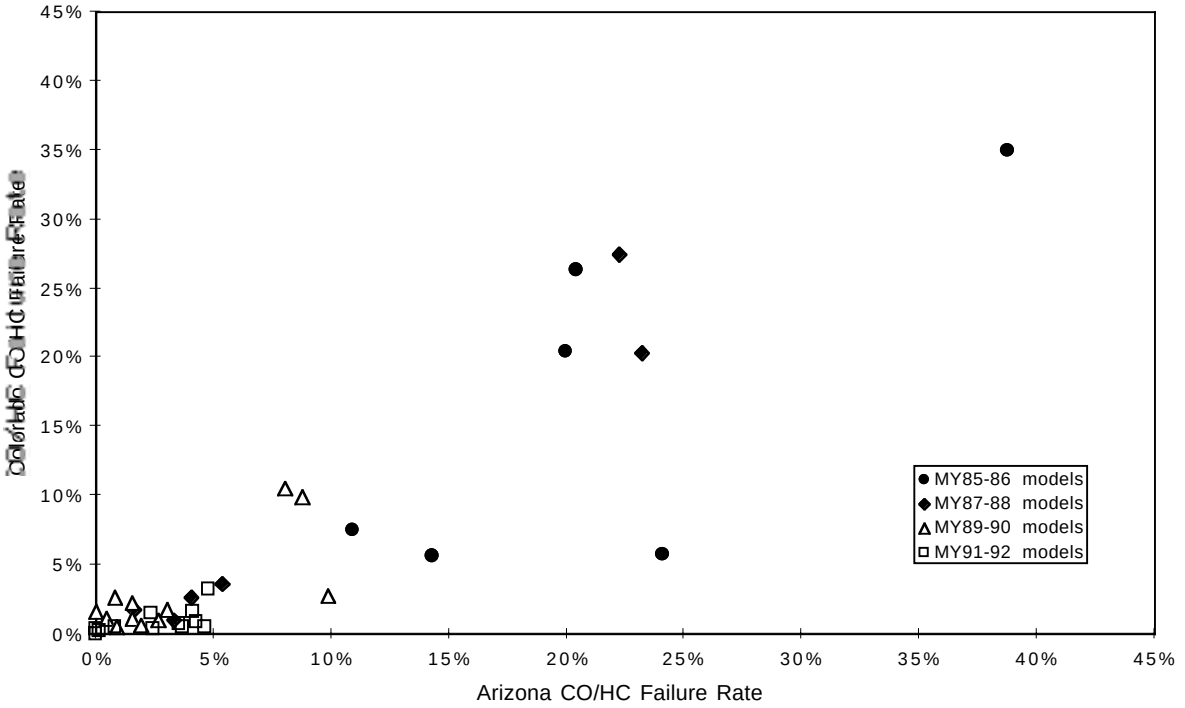
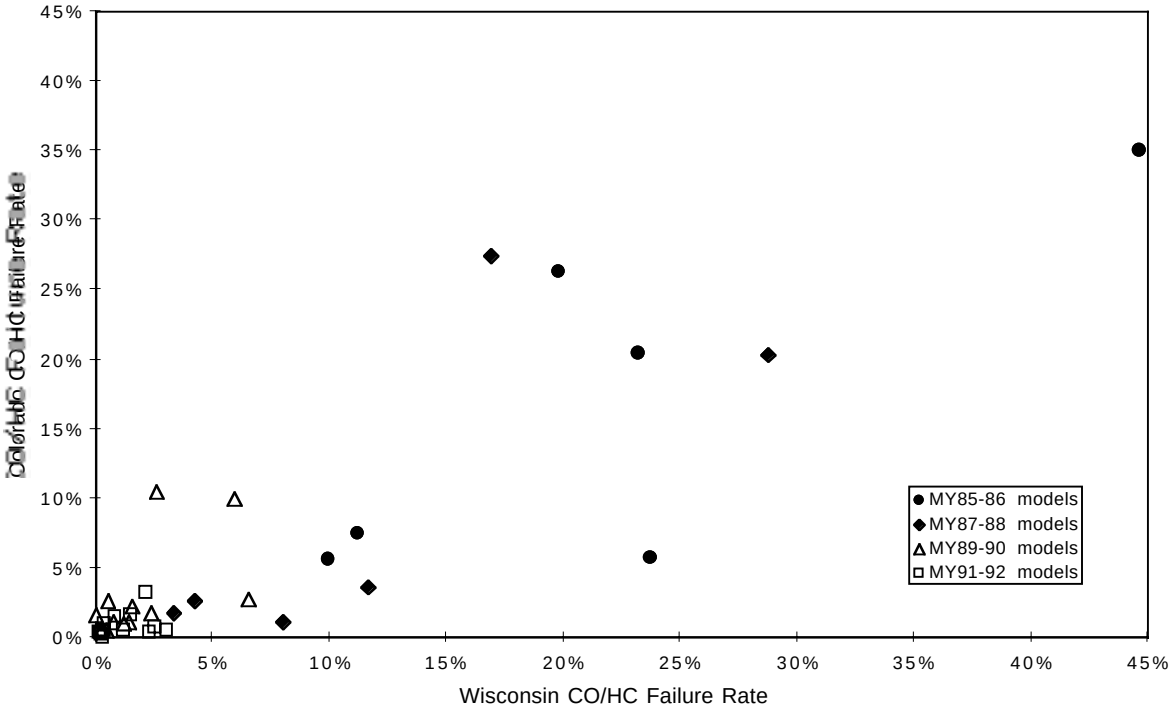


Figure 10. WI v. CO 1997 IM240 Combined CO and HC Failure Rates,
Selected Models



Figures 11 through 13 present a comparison of average emissions from 79 models from the Arizona and Ohio IM240 programs. Since Ohio only provided emissions test results, and not whether individual vehicles passed or failed the IM240, we compared the average emissions by model of vehicles receiving the full test. Unlike Arizona, Ohio does not allow dirty vehicles to fast fail; all failing vehicles are given the full IM240. As a result, there are many more vehicles tested per model in Ohio than in Arizona. Again, we limit the analysis to those models for which at least 10 individual vehicles received the full IM240. The different symbols in the figure distinguish models that have over 20 individual vehicles tested (diamonds) from models with 10 to 20 individual vehicles tested (open triangles).

The figures indicate good agreement in average emissions by model for two IM240 programs. For the most part, this agreement does not appear to weaken when we include the models with relatively few measurements of individual vehicles. The exception is a few models that have substantially higher average CO in the Arizona program than in the Ohio program (the four open triangles near the bottom right corner of Figure 12). Overall, average emissions by model are consistently lower in Ohio than in Arizona, even though: 1) the Ohio models are one to two years older at the time of testing (the Ohio data are more recent); 2) the majority of Ohio cars in our sample are failures, whereas at most about half of the Arizona cars are failures; and 3) Ohio had no previous I/M program prior to the IM240 program (Arizona had an idle program previously).

Summary

Further analysis of Arizona IM240 data indicates that the failure rates by vehicle model are quite consistent over multiple test years. An interesting finding is that the I/M program does not appear to reduce failure rates, particularly for CO; rather, the program merely offsets the expected rate of failure due to vehicle use. Analysis of failure rates by model, and by individual vehicle, over several years of IM240 testing is needed.

Adjusted average emissions by model from vehicles not receiving the full IM240 agree with average emissions by model from full IM240 tests. By developing a satisfactory method to project full IM240 emissions measurements from short test results, we can greatly increase the statistical power of the IM240 data. More work needs to be done to understand the biases in our simple adjustment methodology, and to improve the adjustment procedure.

The comparison of data from three IM240 states shows good agreement in failure rates by vehicle model. However, this analysis is based on a small number of models from several model years. A more detailed analysis of I/M failure rates from multiple states is needed. Preliminary comparison of the Arizona and Ohio IM240 programs indicates good agreement in average emissions by vehicle model. More study is needed to determine why emissions are consistently lower in Ohio.

Figure 11. Average HC by Model, AZ vs. OH

MY90-93 models with at least 10 full IM240 tests

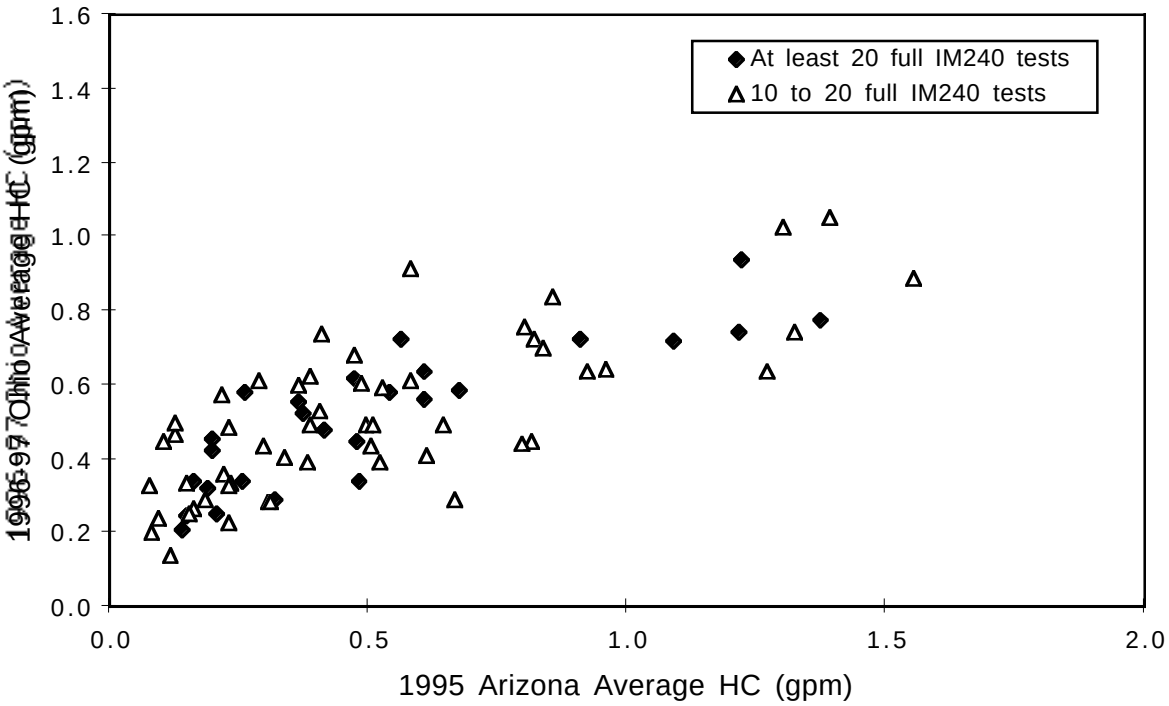


Figure 12. Average CO by Model, AZ vs. OH

MY90-93 models with at least 10 full IM240 tests

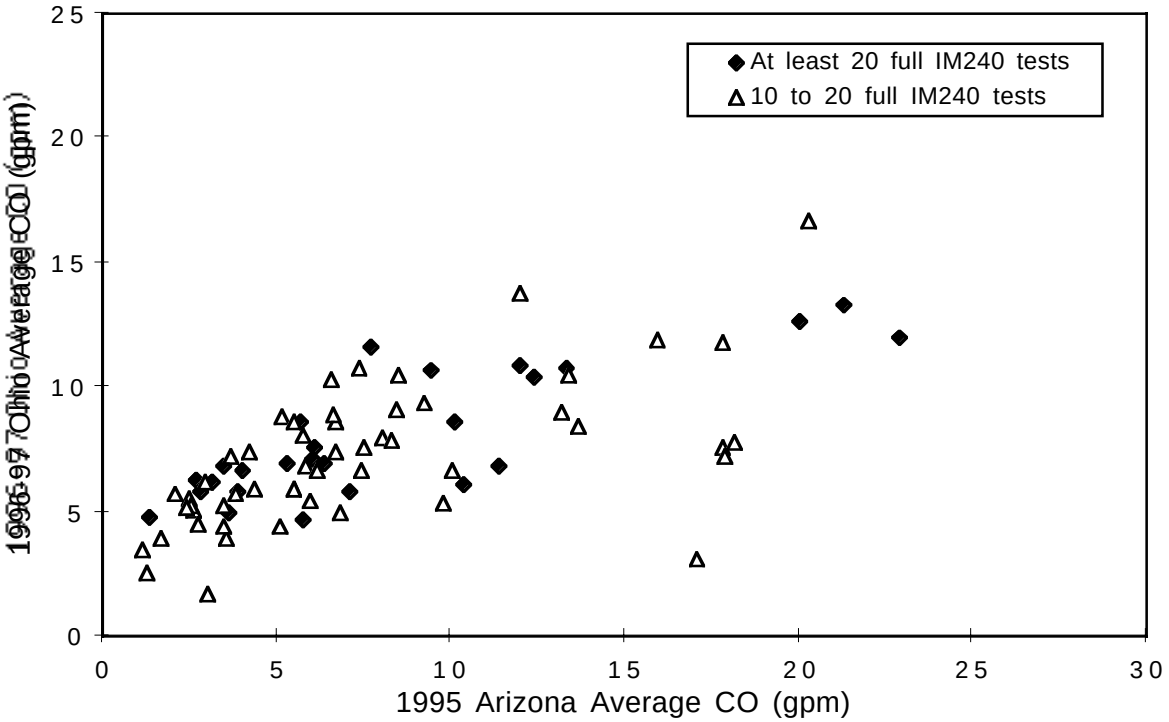


Figure 13. Average NOx by Model, AZ vs. OH

MY90-93 models with at least 10 full IM240 tests